Meta-Analisis_Effect of Blended Learning Model on Mathematical Ability

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Effect of Blended Learning Model on Mathematical Skills: Meta-Analysis Study

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Abstract

(1) Background: Many studies have conducted research on the effect of Blended Learning on mathematical skills, but the results of previous research reported different results. Therefore, this research aims to determine the effect of the blended learning model on mathematical skills; (2) Methods: This research design uses a meta-analysis approach by analyzing 20 effect sizes from 18 primary studies that meet the inclusion criteria. The data analysis method was tested with the support of the OpenMEE application; (3) Results: The results of the analysis show that the use of the blended learning model has an effect on mathematical skills when compared to traditional learning ($d = 0.72$; $p < 0.01$). The results of the analysis according to the moderator variable are known that the effect of the blended learning model on mathematical skills is different based on the level of education (Qb = 144, 62; $p < 0, 01$). However, no differences were found according to the sample size group (Qb= 0.11; $p > 0.05$), platform use (Qb= 0.74; $p > 0.05$), and the year of research (Qb= 1.40). ;$p > 0.05$); (4) Implications: The findings of this meta-analysis show the consistency of research results on the effect of using the blended learning model on students' mathematical skills.

Keywords: Mathematical Skills; Blended Learning; Meta-Analysis

Introduction

Advances in information and communication technology in the 21st century have had a great influence on the world of education, especially in the learning process (Akgunduz & Akinoglu, 2016). With the rapid advancement of educational technology today, the teaching and learning environment has begun to change and develop (Karagol & Esen, 2020). Technology can improve student collaboration (Keser et al., 2011), higher order thinking skills (Kurt, 2010), as well as learning engagement and motivation (Baytak et al., 2011). The integration of technology benefits students to provide extra practice and gives students the opportunity to evaluate their problems and provides the widest opportunity to choose different alternative answers (Juandi & Priatna, 2018; Gonzalez & Birch, 2018; Nurjanah et al., 2020; Sung et al., 2016). In mathematics learning, technology is able to create practical and meaningful mathematics learning, and can visualize mathematical concepts or objects (Herron, 2010; Setyaningrum, 2018). The use of technology in creative learning and according to student needs can assist in developing mathematical knowledge and skills to meet the quality of education and the needs of 21st century society (Chen et al., 2020; Adelabu et al., 2019). Students who can maximize technology as a learning resource are proven to have good math skills (Bulut & Delet, 2011). The availability of technology in the school environment also has a positive influence on academic performance (Hu et al., 2018). Therefore, educators in the learning process are expected to be able to integrate technology in designing learning.

The use of appropriate learning models can improve the quality of the learning process so that it affects the achievement of competence or student learning achievement (Prasetya et al., 2018). The general flow of the learning process is the delivery of material by educators, then making assignments or practicing during class time, but this kind of teacher-centered learning provides time constraints so students are forced to continue their learning activities at home (Cobena et al., 2019) . The results of the study of Sanuaka et al. (2017) also reported that the use of inappropriate strategies and limited time made it difficult for students to develop their skills. Setiawan et al. (2021) revealed that teachers need to apply a learning model that can provide extensive time and provide students with wider opportunities to explore their learning styles. Based on this problem, the blended learning model can be applied because this model provides opportunities for students to explore their styles and adapt to their learning speed.

The blended learning model integrates different online learning and face-to-face learning methods, for example: lectures, independent learning, and online discussions. After students have established an overview of the course, they can then move on to learning and interacting online (Lin et al., 2016). A similar definition by Lalima & Dangwal (2017) states that blended learning integrates direct learning, indirect learning, collaborative learning, and computer-assisted learning. Blended learning requires internet access, but the process is not only displaying the learning web in the classroom, but also using learning strategies that suit student needs. Blended learning can also improve students' affective aspects, and can facilitate independent learning (Tuomainen; 2016), increasing student interest (Hyderali, 2017).

Previous research has proven that blended learning is able to increase learning engagement and overcome the weaknesses of traditional learning approaches. (Dziuban et al., 2018; Alammary et al., 2015). Able to increase flexibility and convenience in learning, learning achievement, and student learning engagement (Graham, 2012). Marco et al. (2013) revealed that the advantages of blended learning include: Increasing access and flexibility, good student response, increasing pedagogical abilities, cost effectiveness, feedback speed, and facilitating access to everyone who needs training.

Many previous studies have identified the effect of blended learning models on students' mathematical skills, but the results of previous research reported ambiguous results. The results of the study (Albawi, 2018; Alsalhi et al., 2020; Mutaqin et al., 2016; Ojaleye & Awofala, 2018; Ulfa & Puspaningtyas, 2020) reveal that blended learning has a great influence on mathematics achievement, but different results were found by (Belanger, 2018; Ramadhani, 2019; Nida et al., 2020) which revealed that blended learning had no significant effect on mathematics achievement. Based on this problem, an effort is needed to combine the previous findings related to the effect of blended learning on mathematical skills to be evaluated quantitatively so as to provide broader and more accurate results. in this case, a meta-analysis approach can be used to evaluate the results of previous studies to reach in-depth and accurate conclusions (Schmidt & Hunter, 2015; Retnawati et al., 2018; Tamur & Juandi, 2020).

So far, there has been no meta-analysis study that specifically examines the effect of using the blended learning model on math skills. Therefore, the purpose of this study is to measure how much impact the use of the blended learning model has on students' mathematical skills, besides that it will also study whether the effect of using the flipped classroom differs according to the moderator variable. This study seeks answers to the following questions:

RQ1 : Does the use of blended learning model affect mathematival skills?

RQ2 : Does the impact of using the blended learning model on math skills differ according to education level, sample size, media platform, and year of research?

Method

Research Design and Procedure

The design of this study used a group contrast meta-analysis approach. This approach is used to examine the results of research that examines the effectiveness of the blended learning model on mathematical skills. In general, the procedure in this meta-analysis study refers to Borenstein et al. (2009) and Retnawati el al. (2018), among others; 1) determine inclusion criteria, 2) study search, data collection and coding of variables, 3) statistical analysis.

Inclusion Criteria

Determination of inclusion criteria to facilitate the search for studies at a later stage. the studies collected in the initial search were then examined and assessed using the inclusion criteria defined for inclusion in meta-analysis and further evaluation. The inclusion criteria established in this meta-analysis included:

1. The year of publication ranges from 2014 to 2021;
2. Studies can be in the form of doctoral theses and articles published in national or international journals;
3. Articles or doctoral theses are written in English;
4. Studies using experimental or quasi-experimental research methods;
5. There is at least 1 experimental group with blended learning and the comparison group as a control group with traditional learning;
6. The study must report the mean, standard deviation and sample size of each experimental group and control group; or sample size and t-value; or sample size and p-value; or sample size with F-value

Data Collection and Coding

The stage of collecting relevant studies uses online databases such as Google Scholar, ERIC, Elsevier, and others. The keywords used in searching the relevant literature are "Effect or Impact or Effectiveness of Blended Learning on Mathematical Ability or Mathematical Skills". From the research search results based on the specified criteria, 18 studies were collected from 119 initial search studies.

After getting an article that is eligible (meets the inclusion criteria), then identify the characteristics of the literature by coding. The coding in this study was carried out by two people (raters) so that subjective errors could be avoided. The coding content includes information; 1) Education Level; 2) Sample size of the experimental group; 3) Platform used; 4) Year of Research; 5) Frequency; and 6) Percentage. Table 1 presents a summary of the coding results.

Table 1. Studies included in the Meta-analysis

Educational stage	**Frecuency**	**Percentage**
Primary School	3	15.00%
Junior High School	6	30.00%
Senior High School	6	30.00%
University	5	25.00%
Sample Size	**Frecuency**	**Percentage**
Big (> 30)	16	80.00%
Small (< 30)	4	20.00%
Media Platform	**Frecuency**	**Percentage**
LMS	16	80.00%
Social Media	4	20.00%
Year of Study	**Frecuency**	**Percentage**
2014-2017	16	80.00%
2018-2021	4	20.00%

Data analysis

Data analysis in this meta-analysis study was analyzed using OpenMEE software. The data analysis procedure followed the following steps: 1) calculating the effect size of each study; 2) perform heterogeneity test; 3) Calculating summary or combined effects; 4) Test and analyze moderator variables; 5) Test for publication bias.

The classification of each effect size or combined effect of this meta-analysis study follows the classification of Cohen et al. (2018) which is shown in table 2 below:

Table 2. Categories of effect size groups using the Cohen interpretation

Classification	**Interval**
Ignored	0.00 < effect size ≤ 0.19
Small Effect	0.19 < effect size ≤ 0.49
Medium Effect	0.49 < effect size ≤ 0.79
Large Effect	0.79 < effect size ≤ 1.29
Very Large Effect	effect size > 1.29

Before calculating effect sizes from meta-analytical studies, heterogeneity was first tested. The heterogeneity test aims to select the appropriate effect size measurement model. The heterogeneity test in this study uses the Q parameter. The decision-making criteria is if the p-value <0.05, then the measurement model used to calculate the effect size is a random effect, and if the p-value> 0.05 then the fixed effect is used (Retnawati et al., 2018; Borenstein et al., 2009). Furthermore, to ensure that the research included in the meta-analysis has shown results that are in accordance with field conditions (objective), a publication bias test is carried out (Muhtadi et al., 2022; Retnawati et al., 2018; Juandi & Tamur, 2020; Setiawan al., 2022). The approach used to evaluate publication bias is File-Safe N (FSN). if the FSN value is greater than 5k + 1, where k is the number of studies, it can be concluded that there is no publication bias problem..

Results

Characteristics and Effect Sizes of Each Study

The first step in this meta-analysis was to calculate the effect size of each study. Study effect sizes were calculated with the help of OpenMEE software. Effect size values range from -0.201 to 1.965. Table 3 provides a summary of the effect size values, for each study.

Table 3. Effect Size of Each Study

No	**Author**	**Year**	**Educational Stage**	**Platform**	**Effect Size**
1	Albawi	2018	University	LMS	1.965
2	Alsalhi et al.	2020	University	LMS	2.058
3	Balabag & Dorado	2019	Senior High School	LMS	0.525
4	Belanger	2018	Primary School	LMS	-0.942
5	Belanger	2018	Primary School	LMS	-0.044
6	Lin et al	2015	Primary School	LMS	0.356

7	Makkar & Sharma	2017	Senior High School	LMS	0.568
8	Mutaqin et al	2016	University	LMS	1.576
9	Nida et al	2020	Junior High School	Social Media	0.231
10	Ojaleye & Awofala	2018	Senior High School	Social Media	1.148
11	Olpak & Baltaci	2018	University	LMS	0.864
12	Pertiwi et al	2018	Junior High School	LMS	0.907
13	Ramadhani	2019	Senior High School	LMS	0.108
14	Setyaningrum	2018	Junior High School	LMS	0.454
15	Skelton	2017	Junior High School	LMS	0.403
16	Suarsana et al	2019	Senior High School	LMS	0.695
17	Suarsana et al	2019	Senior High School	LMS	1.300
18	Tseng et al	2014	Junior High School	Social Media	0.248
19	Ulfa & Puspaningtyas	2020	University	LMS	1.374
20	Wei et al	2020	Junior High School	Social Media	0.621

Based on table 3 above, out of a total of 20 effect sizes, three effect sizes (n = 3) were classified as negligible effects, five effect sizes (n = 5) were classified as small effects, four effect sizes (n = 4) were classified as moderate effects. , three effect sizes (n = 3) were classified as large effects, and five effect sizes (n = 5) were classified as very large effects. Figure 1 presents the number of effect size classifications.

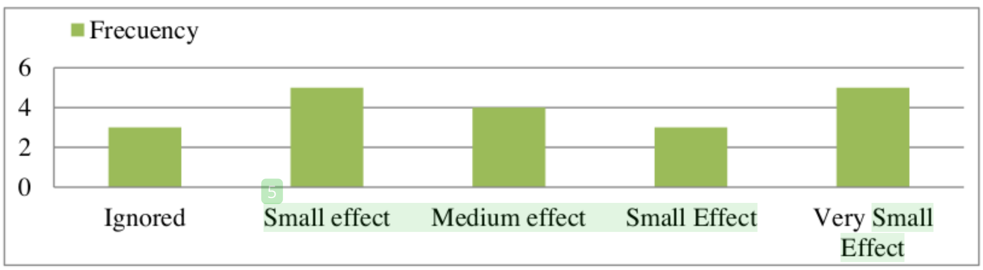

Figure 1. Effect size classification

Heterogeneity Test and Overall Effect Size

The heterogeneity test aims to select a suitable model to calculate the combined effect size. There are many approaches used to test for heterogeneity, but in this study the Q parameter approach was used or by looking at the p value. If the p value < 0.05 then the effect size variance is heterogeneous so a random effects model is used, and if the p value > 0.05 then the effect size variance is homogeneous so the model used is a fixed effect. Table 4 presents a summary of heterogeneity tests and combined effect sizes.

Tabel 4. Heterogeneity test summary and combined effect sizes

Model	k	Effect Size (d)	[95% CI]	p	df	Heterogeneity		
						Q	p	I^2
Random	20	0.72	[0.40, 1.03]	< 0.001	19	199.08	< 0.001	90.45%
Fixed	20	0.73	[0.64, 0.83]	< 0.001	19			

The results of the heterogeneity test (see table 2) show the Q value is 199.08. Since this value is greater than the chi-square value (df = 19) and the p value < 0.05, it can be concluded that the studies conducted to calculate the effect size were heterogeneous. The I^2 value found to reach 90.45% reflects high heterogeneity (Higgins et al., 2003). Since the studies used were heterogeneous, the overall effect size value was based on the random effects model. Based on the random effects model, the effect size value is 0.886. This effect size is in the large category (Cohen et al., 2018). Thus, these results reveal that the use of blended learning has a major effect on students' mathematical abilities.

Moderator Variable Analysis

Because the analyzed studies are heterogeneous in distribution, it is potential to analyze moderator variables. The moderator variables identified in this study were education level, sample size, skills measured, year, technology media, and region. Table 5 presents the results of the analysis of moderator variables.

Table 5. Results of combined effect sizes and analysis of moderator variables

Moderator Variables	k	Effect Size (d)	P	Heterogeneity				
				Q	df	Qw	Qb	p
Educational stage								
Primary School	3	-0.22	0.56	14.26	3	54.46	144.62	0.00
Junior High School	6	0.45	< 0.01	6.40				
Senior High School	6	0.75	< 0.01	19.73				
University	5	1.60	< 0.01	14.07				
Sample Size								
Big (> 30)	16	0.71	< 0.01	186.32	1	198.97	0.11	0.74
Small (< 30)	4	0.75	0.01	12.65				
Media Platform								
LMS	16	0.76	< 0.01	175.79	1	198.34	0.74	0.39
Social Media	4	0.58	0.02	22.55				
Year of Study								
2014-2017	16	0.67	0.01	12.61	1	197.68	1.40	0.24
2018-2021	4	0.73	< 0.01	185.07				

Note. k = the number of studies; Qw = Q within; Qb = Q between.

Educational stage

The moderator variable for education level consists of four groups, namely elementary, junior high, high school, and university. The results of the analysis (see Table 5) found that the mean effect sizes of the four levels were significantly different ($Qb = 144.62$; $p < 0.05$). These results indicate that the effectiveness of blended learning compared to traditional learning in terms of mathematical abilities differs according to education level. The use of blended learning was most effective in the university group ($d = 1.60$; $p < 0.01$), followed by the high school group ($d = 0.75$; $p < 0.01$), and junior high school ($d = 0.45$; $p < 0.01$). Meanwhile, the

SD group did not prove significant ($d = -0.22$; $p > 0.05$). These results reveal that blended learning is not proven effective when compared to traditional learning at the elementary level.

Sample Size

The moderator variable of sample size consists of two groups, namely small and large sample groups. The results of the analysis (see Table 5) found that the effect size in the small sample group was ($d = 0.75$; $p < 0.01$) and the effect size in the large sample group was ($d = 0.71$; p , 0.05). The effect sizes of the two groups are in the medium category. Based on the difference test, it was found that the average effect size of the two sample size groups was not significantly different ($Qb = 0.11$; $p > 0.05$). These results indicate that the effect of blended learning compared to traditional learning in terms of mathematical ability does not differ according to sample size.

Media Platform

The moderator variables used consisted of two groups, namely LMS and social media. The results of the analysis (see Table 5) found that the effect size of using LMS was ($d = 0.76$; $p < 0.01$) and the effect size of social media use was ($d = 0.58$; $p < 0.05$). The effect sizes of the two groups are in the medium category. Based on the difference test, it was found that the average effect size of the two groups using the media platform was not significantly different ($Qb = 0.74$; $p > 0.05$). These results indicate that the effect of blended learning compared to traditional learning in terms of mathematical ability does not differ according to the use of the media platform.

Year of Study

The moderator variables of the research year used consisted of two groups, namely 2014-2017 and 2018-2021. The results of the analysis (see Table 5) found that the effect size of the 2014-2107 group was ($d = 0.67$; $p < 0.05$) and the group effect size of 2018-2021 was ($d = 0.73$; $p < 0.01$). The effect sizes of the two groups are in the medium category. Based on the difference test, it was found that the average effect size of the two study years did not differ significantly ($Qb = 1.40$; $p > 0.05$). These results indicate that the effect of blended learning compared to traditional learning in terms of mathematical ability does not differ according to the research year group.

Evaluation of Publication Bias

Meta-analytical studies that are scientifically justified and reflect objectivity can be assessed by evaluation of publication bias. this study examines publication bias with the File-Safe N (FSN) approach. The results of the analysis (see table 6) were obtained ($FSN = 1495 > 5k+1= 110$). These results suggest that this meta-analysis study does not have publication bias issues. The following table provides a summary of the evaluation of publication bias.

Table 6. File-Safe N

File Drawer Analysis				
	k	**Fail-safe N**	**Target Significance**	**Observed Significance**
Rosenthal	20	1495	0.05	< 0.001

Discussion

The results of the analysis show that the overall effect size using the random effects model is (d = 0.72; k = 20). These results indicate that overall mathematical ability using the blended learning model is more effective than traditional learning. These results are in line with the findings of Setiawan et al. (2022) who conducted a meta-analysis of studies in Indonesia. Their findings show that students' mathematical abilities using blended learning are more effective than traditional learning. Another finding that is also in line with this study is the meta-analysis conducted by Lusa et al. (2021). Although the variables do not focus on mathematical ability, their findings reveal that blended learning has a positive effect on thinking skills, motivation and learning independence. The blended learning model is more effective than traditional learning because in traditional learning, students cannot develop at their own pace, and if they are stuck, it is difficult to catch up on what they have missed. However, when using technology-assisted blended learning, each student can control their learning progress and they can learn without being distracted. Students can browse the learning materials as much as they need and repeat the exercises to understand the content, and can more broadly explore their learning styles (Hung, 2007; Liu, 2010; Wang & Yu; 2012; Wiginton, 2013; Lin et al., 2016) .

Based on the moderator variable of education level, the results of the analysis show that the effect of applying the blended learning model on mathematical abilities differs according to education level. The application of the blended learning model has a positive effect at the university, high school, and junior high school levels. Meanwhile, at the elementary school level, it did not have a positive impact. These results are in line with the findings of Belanger (2018) in the United States. The findings reveal that elementary school students' mathematics learning outcomes using traditional learning are better than blended learning. Other results that also support this research are the findings of the meta-analysis of Strelan et al (2020) which found that blended learning using the flipped classroom method had a small effect. These results suggest that to obtain the effectiveness of the application of blended learning, it should be applied at a higher level. In addition, future research needs to conduct a meta-analysis specifically at the elementary school level to obtain broader and more accurate conclusions.

Based on the sample size moderator variable, the results of the analysis show that the effectiveness of using the blended learning model when compared to traditional teaching on math skills is not significantly different. These results indicate that the use of blended learning on mathematical abilities is equally effective when applied to a small sample group ($\leq$ 30) and a group with a large sample size (31). Thus the difference in research sample size does not change the size of the effect of studies comparing the application of blended learning and conventional models to students' mathematical abilities. This result is different from the findings (Yakar, 2021; Karagon & Esen, 2019). Their findings show that small sample sizes produce larger effect sizes. To achieve consistent results it is necessary to involve more primary studies in the analysis.

Based on the moderating variable of the use of technology media, the results of the analysis show that the effectiveness of the use of blended learning models when compared to traditional teaching on mathematical abilities is not significantly different. These results indicate that the use of blended learning on mathematical abilities is equally effective when applied to groups using LMS technology and groups using social media technology. However, another fact was also found that the use of LMS was not proven to be effective at the elementary school level as in research (Belanger, 2018). The use of LMS also has little effect at the elementary school level (Lin et al., 2015). A different result was found by Ramadhani (2019) which showed that the use of LMS did not have a significant effect at the high school level. While the use of social media was also found to be effective at the high school level (Ojaleye & Awofala, 2018), but at the junior high school level, the use of social media tends to have a small effect (Tseng et al., 2014; Nida et al., 2020). Differences in results related to the use of technology media in blended learning provide suggestions for future research to conduct a meta-analysis related to the use of technology media in supporting blended learning learning by involving more studies.

Based on the moderator variable in the year of research, the results of the analysis show that the effectiveness of the use of the blended learning model when compared to traditional teaching on mathematical abilities is not significantly different. The use of the blended learning model in the 2018-2021 group provides a larger effect size than in 2014-2017, we speculate that the use of the blended learning model in the current research year has gone through a development process from previous years, so the results obtained will be better from the previous year. However, there was no significant difference between the two groups. These results indicate that overall the use of blended learning on math skills has been proven to be effective in 2014-2017 and 2018-2021. This finding is supported by a previous meta-analysis by Vo et al. (2017) which investigated variations in primary study outcomes by year of study.

Conclusion

The results of the analysis show that the application of the flipped classroom model has an effect on students' mathematical abilities compared to the application of the traditional approach. Based on the analysis of the moderator variable, it is known that the effect of the flipped classroom model on mathematical abilities differs according to the educational level group. but did not differ by sample size group, media platform, and year of study. The findings of this meta-analysis show the consistency of the publication of research results on the effect of using the reverse class model on students' mathematical abilities.

Apart from the validation results reported, this study also has limitations. This study only analyzed 20 effect sizes. This study also only analyzes mathematical abilities in general. Further research needs to expand the research sample and analyze mathematical abilities more specifically, for example: critical thinking skills, mathematical communication, and others. In addition, it is also recommended to be more specific in reviewing the analysis of moderator variables in this study by involving more research so that research findings become more accurate.

Conflicts of Interest

The author declares that there is no conflict of interest in connection with the publication of this manuscript. In addition, ethical issues, including plagiarism, infringement, falsification and/or falsification of data, publication and/or double submission, and redundancy are fully borne by the authors.

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